As to the dynamo part it is half generator, receiving mechanical power by transmission along the shaft to furnish half its output, and it is half converter, turning the currents received from the armature into direct current delivered at the brushes.

Ques. What action takes place in the motor armature winding?

Ans. Since it runs at one-half synchronous speed, it generates alternating current of half the supply current frequency, delivering these to the armature of the dynamo.

Ques. What claim is made for this type of apparatus?

Ans. The cost is said to be less than a motor generator set, and it is claimed to be self-synchronizing and to require no special starting gear, also to be 2.5 per cent. more efficient than a motor generator.

Ques. How is the machine started from the high pressure side?

Ans. The field winding is connected directly to the high pressure leads. The three slip ring brushes are connected with external resistances which are used while starting, the external resistances being gradually cut out of the circuit as the machine comes up to speed (the same as with an ordinary slip ring motor).

Ques. How does a cascade converter compare with a synchronous converter?

Ans. It is about equally expensive as the synchronous converter with its necessary bank of transformers, but is about one per cent. less efficient. It is claimed to be more desirable for frequencies above 40 on account of the improved commutation at the low frequency used in the dynamo member. For lower frequencies the synchronous converter is preferable.

CHAPTER LIV

RECTIFIERS

The purpose of a rectifier is to change alternating current into a uni-directional or pulsating current. There are several classes of apparatus to which the term rectifier may be applied, as

1. Mechanical rectifiers;
2. Electrolytic rectifiers;
3. Mercury vapor rectifiers, or, mercury arc rectifiers;
4. Electro-magnetic rectifiers.

Mechanical Rectifiers.—By definition, a mechanical rectifier is a form of commutator operating in synchronism with the generator and commutating or rectifying the negative waves of the alternating current as shown graphically in figs. 2,076 and 2,078. The essential features of construction are shown in fig. 2,079.

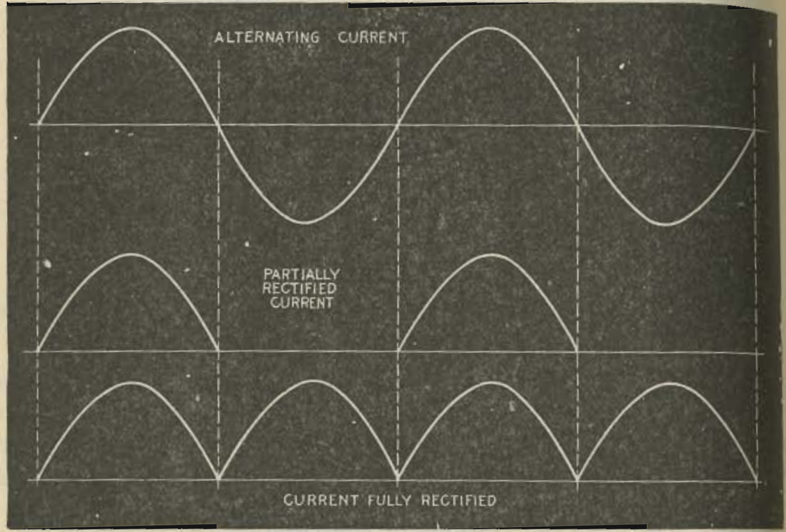
Ques. Mention some application of a mechanical rectifier.

Ans. It is used on a compositely excited alternator as illustrated on page 1,192.

Electrolytic Rectifiers.—If two metals be placed in an electrolyte and then subjected to a definite difference of pressure, *they will* (under certain conditions) *offer greater resistance to the* *passage of a current in one direction, than in the other direction.* On account of this so called valve effect, electrolytic rectifiers are sometimes called "valves."

Ques. What metal is generally used for the cathode?

Ans. Aluminum.



FIGS. 2,076 to 2,078.—Diagrams showing alternating currents, and partial and complete rectification.

Ques. What is generally used for the other electrode?

Ans. Lead or polished steel.

Metals of low atomic weight exhibit the valve effect at high differences of pressure, and heavier metals at low differences of pressure.

Ques. Describe the "Nodon valve."

Ans. The cathode is of aluminum or aluminum alloy, and the other electrode, which has considerably more surface, is the containing vessel. The electrolyte is a neutral solution of ammonia phosphate.

Ques. Describe its action.

Ans. It is due to the formation of a **film** of normal hydroxide of aluminum, over the surface of the aluminum electrode. This film presents a very high resistance to the current when flowing in one direction but very little resistance, when flowing in the reverse direction.

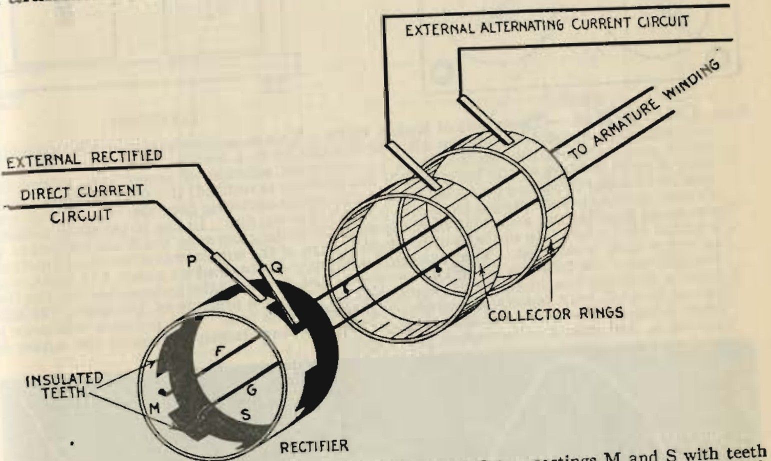
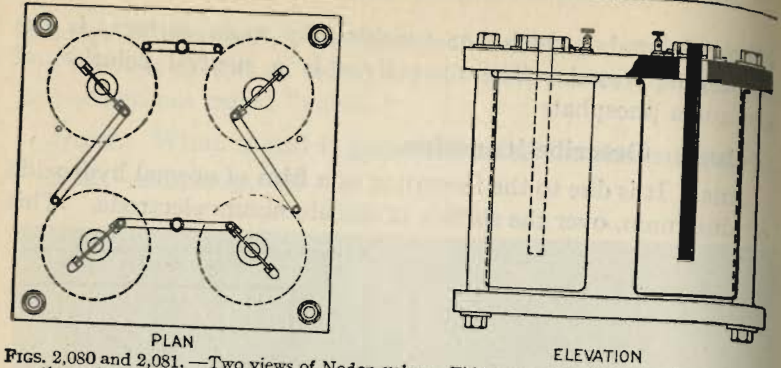

EXTERNAL ALTERNATING CURRENT CIRCUIT
TO ARMATURE WINDING
EXTERNAL RECTIFIED DIRECT CURRENT CIRCUIT
P
Q
COLLECTOR RINGS
F
G
S
M
INSULATED TEETH
RECTIFIER

FIG. 2,079.—Mechanical rectifier. The rectifier consists of two castings M and S with teeth which fit together as shown, being insulated so they do not come in contact with each other. Every alternate tooth, being of the same casting, is connected together, the same as though joined by a conducting wire. There are as many teeth as there are poles. The part M of the rectifier is connected to one of the collector rings by F, and the part S to the other ring by G.

Ques. What is the effect when a Nodon cell is supplied with alternating current?

Ans. Half of the wave will be suppressed and an intermittently pulsating current will result as shown in fig. 2,077.



FIGS. 2,080 and 2,081.—Two views of Nodon valve. This is an electrolytic rectifier in which the cathode is a rod of aluminum alloy held centrally in a leaden vessel which forms the anode and contains the electrolyte, a concentrated solution of ammonium phosphate. Only a short portion at the lower end of the cathode is utilized, the rest, which is rather smaller in diameter, being protected from action by an enclosing glass sleeve. The current density at the cathode ranges from 5 to 10 amp. per sq. dm. In the larger sizes, the cells are made double, and a current of air is kept circulating between the walls by means of a motor driven fan. In order to utilize both halves of the supply wave, the Gratz method of connection is adopted. The maximum efficiency is obtained at about 140 volts, and the efficiency lies between 65 and 75 per cent., and is practically independent of the frequency between the limits of 25 ~ and 200 ~. Above a pressure of 140 volts, the efficiency falls off very rapidly, owing to breakdown of the film. The pressure difference is high, being over 90 per cent. at full load. Temperature largely influences the action of the valve, and should never exceed 122° Fahr.

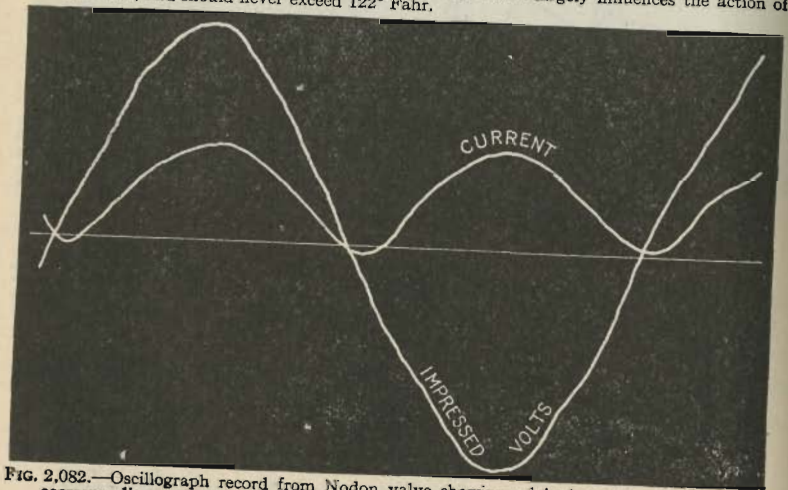


FIG. 2,082.—Oscillograph record from Nodon valve showing original supply voltage and the corresponding pulsating current at the terminals of such a valve.

Ques. How may both halves of the alternating waves be utilized?

Ans. By coupling a series of cells in opposed pairs as in fig. 2,080.

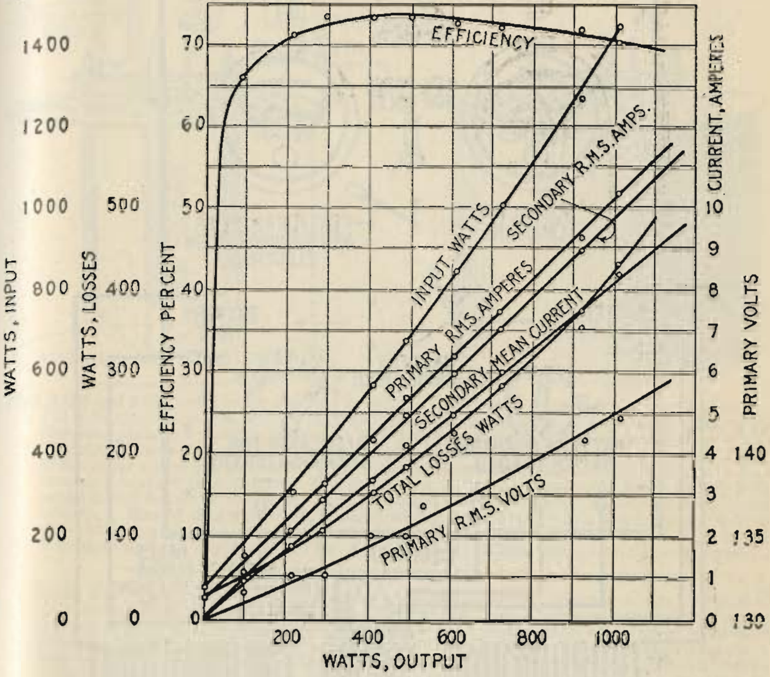


FIG. 2,083.—Performance curves of five ampere Nodan valve. Constant secondary voltage test. Loaded on non-inductive resistances. Frequency 50. Maximum power factor on valve .7.

Ques. Upon what does the efficiency of the film depend?

Ans. Upon the temperature.

It should not for maximum efficiency exceed 86 degrees Fahr. There is also a certain critical voltage above which the film breaks down locally, giving rise to a luminous and somewhat disruptive discharge accompanied by a rapid rise of temperature and fall in efficiency.

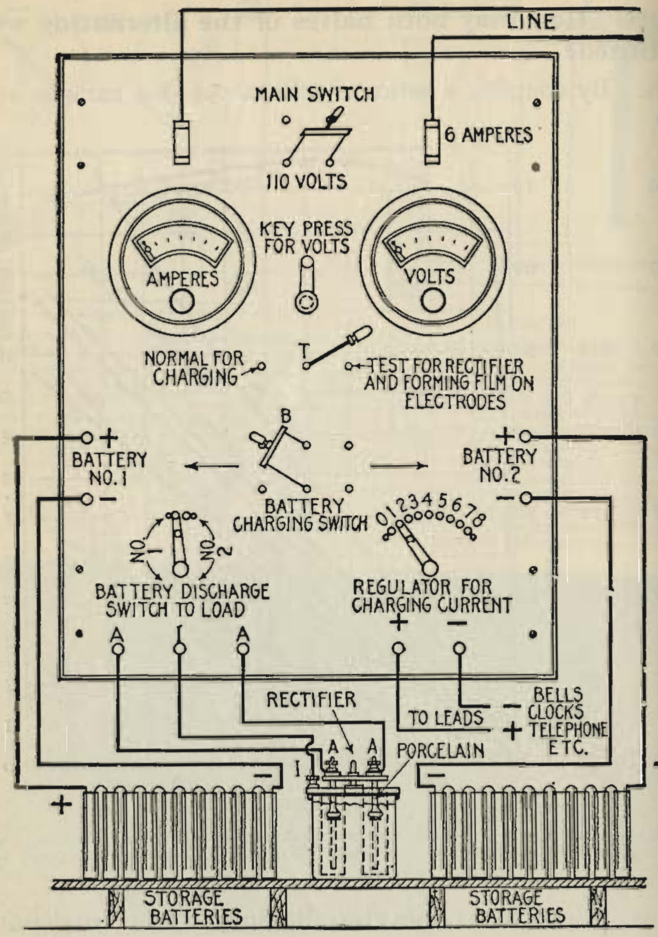
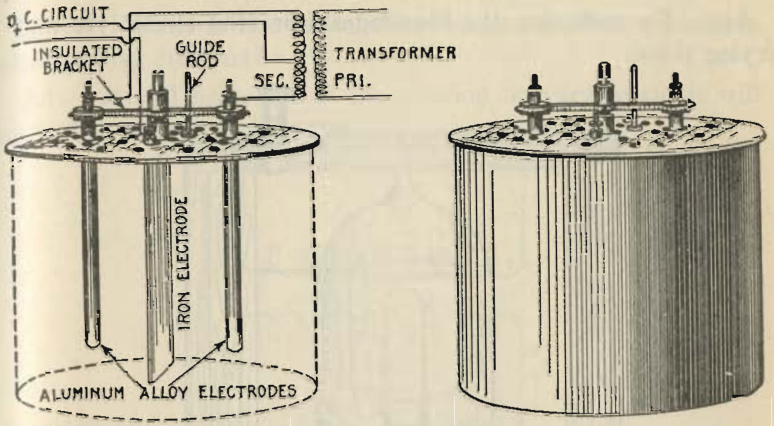


FIG. 2,084.—Mohawk electrolytic rectifier and switchboard; diagram showing connections for charging storage battery. **Operating instructions:** After assembling battery as in fig. 2,085, the **film** must be formed on the aluminum alloy electrodes so that the rectifier will pass current only in the right direction. Open switch B, close switch T to the right; discharge lever can be in any position; charging regulator lever must be to the extreme left, the zero position; now close main switch M. Moving regulator lever R from the zero position to the first button or contact, let it remain there for a time. **not less than five minutes**; *this is important*, as the proper rectification of the current depends on the film formed on the aluminum rods. The ammeter after the first rush of current may not show any current as passing, or it may show a reverse current. In the latter case, leave the contact finger on the first button until the needle comes back to zero. This may take some time, but the needle will eventually come back; it also indicates that the film is properly formed when the needle returns to zero. Move regulator R to the extreme right step by step and note that the ammeter continues to return to zero, which indicates that the film on rectifier electrodes is formed properly. Move regulator R to zero, close switch T to the left in normal charging position. Close charging switch B. To regulate the flow of current through the battery move charging lever R to the right slowly until ammeter indicates the correct charging current. After the batteries are charged and ready for use, discharge lever can be moved to connect either set of storage batteries to the load terminal. The voltage of the batteries can be read at any time, by pressing the strap key. The discharge lever connects the batteries to the volt meter and it is possible by moving it to measure the voltage of either set of battery, charging or discharging. Trouble in the rectifier demonstrates itself by the solution becoming heated. The condition of the rectifier can be tested any time in a few seconds by opening switch B and closing switch T to the right. If the rectifier be in proper condition the ammeter will read zero. And if it be not rectifying and permitting A.C. current to flow through the rectifier, the ammeter will read negative or to the left of the zero. An old solution that is heating and not rectifying properly will turn a reddish brown color.

Ques. When an electrolytic rectifier is not in use for some time what happens?

Ans. The electrodes will loose the film.



FIGS. 2,085 and 2,086.—Mohawk electrolytic rectifier. To put in commission, clean out the jar. Fill with distilled or rain water. Add six pounds of electro salts, stir and after all salts are dissolved place the cover in position. The specific gravity of the solution should be 1.125. The middle iron electrode must hang straight down in the solution and not touch either of the other aluminum alloy electrodes. The aluminum alloy electrodes are mounted on an insulated bracket that slides up and down on a ¼″ rod. This rod screws in the hole taped in the middle of the cover. The electrodes give the best results only when perfectly smooth, Should they get rough, covered with a deposit or a white coating remove from the solution, and clean with fine sand paper. Finish with fine sand paper. Form the film again and the electrodes will be as good as new. Clean iron electrode occasionally.

Ques. What must be done in such case?

Ans. The electrodes must be reformed.

Ques. How is the loss of film prevented?

Ans. By removing the electrodes from the electrolyte and drying them.

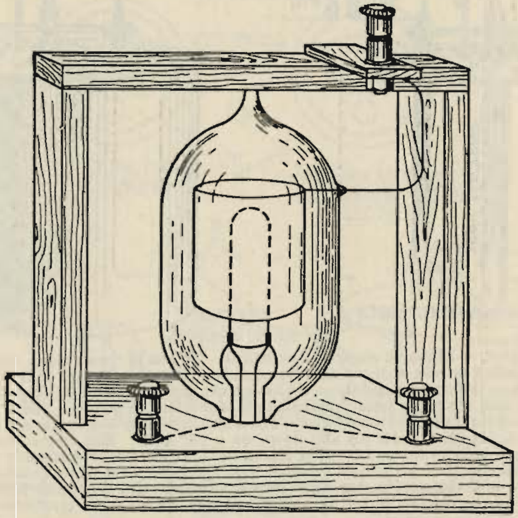


FIG. 2,087.—The Fleming oscillation valve. It depends for its action on the well-known Edison effect in glow lamps. The valve consists of a carbon filament glow lamp with a simple central horseshoe filament. Around this filament inside the exhausted bulb is fixed a small cylinder of nickel, which is connected by means of a platinum wire sealed through the bulb to a third terminal. **The valve is used as follows:** *The carbon loop is made incandescent by a suitable battery. The circuits in which the oscillations are to be detected is joined in series with a sensitive mirror galvanometer, the nickel cylinder terminal and the negative terminal of the filament of the valve being used.* The galvanometer will then be traversed by a series of rapid discharges all in the same direction, those in the opposite direction being entirely suppressed.

Ques. What attention must be given to the electrolyte?

Ans. Water must be added from time to time to make up for evaporation.

This is necessary to keep the solution at the proper density.

Ques. What is the indication that the rectifier needs recharging?

Ans. Excessive heating of the solution with normal load.

Ques. What is the indication that a rectifier is passing alternating current?

Ans. It will heat, and if the solution be very weak, it will cause a buzzing sound.

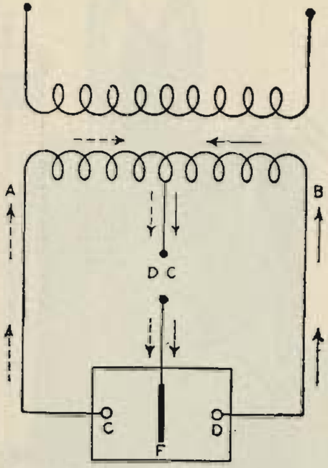


FIG. 2,088.—The Churcher valve. This is of the modified Nodon type. It differs from the latter in that it has two cathodes of aluminum and an anode of lead or platinum, suspended in the one cell. This permits the complete utilization of both halves of the supply wave with one cell instead of the four required in the Gratz method. The connections of such a cell are shown in the figure. The secondary of the transformer carries a central tapping, and is connected through the direct current load to the central anode, while each of the cathodes is connected to the ordinary terminals of the transformer itself. The practical limits of the cell are 50 volts direct current, or 130 volts at the transformer terminals AB. F, is the anode; C. cathode I; D, cathode II.

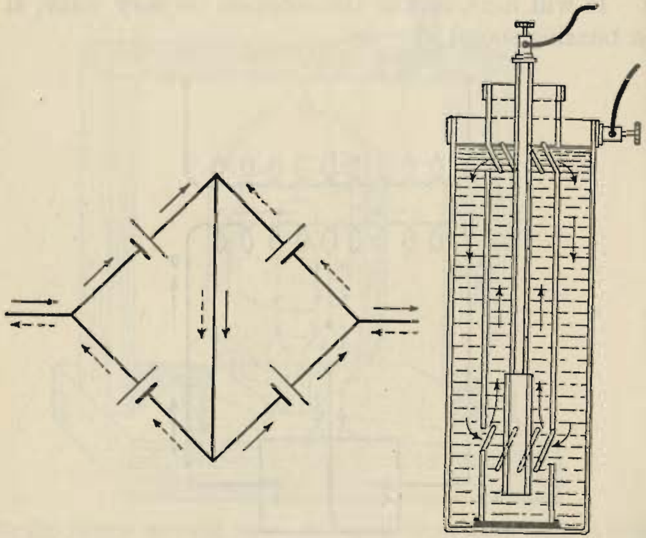
Ques. What harm is caused by operating a rectifier with a weak electrolyte?

Ans. The electrodes will eat away.

A few of the so called electrolytic valves are here briefly described:

The Audion Valve.—This valve was invented by De Forest in 1900 and is practically identical with the Fleming oscillation valve, the latter being illustrated in fig. 2,087.

Grisson Valve.—In this valve the cathode is a sheet of aluminum, and the anode, a sheet of lead, supported, in the original form, horizontally in a vessel containing the electrolyte, consisting of a solution of sodium carbonate. Cooling is effected by circulating water through metal tubes in the electrolyte itself.



FIGS. 2,089 and 2,090.—The De Faria valve. This is an aluminum lead rectifier. The cathode is a hollow cylinder of aluminum placed concentrically in a larger cylinder of lead, and the whole immersed in electrolyte of sodium phosphate in an ebonite containing vessel. Cooling is effected by promoting automatic circulation of the electrolyte by providing the lead cylinder with holes near its extremities; the heated electrolyte then rises in the lead cylinder, passes out at the upper holes, is cooled by contact with the walls of the containing vessel, and descends outside the lead cylinder. It is claimed that this cooling action is sufficient to allow of a current density of 8 amp. per sq. dm. of aluminum.

Pawlowski Valve.—This is an electrolytic valve employing a solid electrolyte. It consists of a copper plate which has been coated with a crystalline layer of carefully prepared copper hemisulphide, prepared by melting sulphur and copper together out of contact with air. The prepared plate is placed in contact with an aluminum sheet and the combination is then *formed* by submitting it to an alternating pressure until sparking, which at first occurs, ceases.

Giles Electric Valve.—This consists of a combination of spark gaps and capacity used to protect electrical apparatus against damage due to atmospheric discharges and resonance surges. The spark gaps are formed between the edges of sharp rimmed discs of non-arcing metal. These discs are insulated from each other, and from the central tube, which provides a support for the apparatus and also an earth. The condenser effect is obtained by means of the annular discs and the tube; an adjustable spark gap, a high resistance, and a fuse all connected in series, complete the valve.

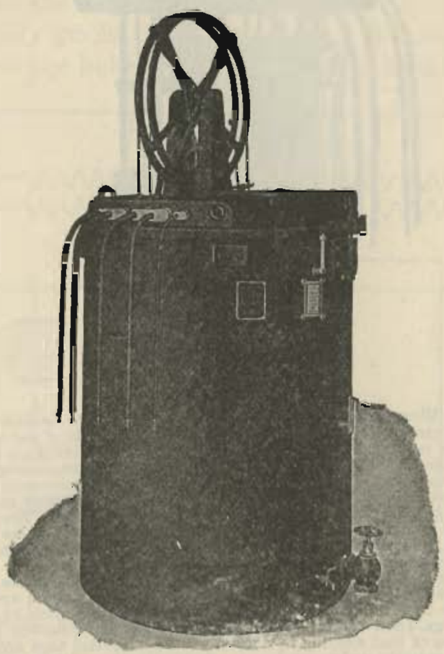


FIG. 2,091.—75 light Westinghouse-Cooper Hewitt mercury vapor rectifier constant current regulating transformer. View showing assembly in case.

Buttner Valve.—It is of the Nodon type employing a cathode of magnesium-aluminum alloy, and probably iron or lead as anode, with an electrolyte of ammonium borate. Buttner claims that the borate is superior to the phosphate in that it does not attack iron, and will keep in good working condition for longer periods.

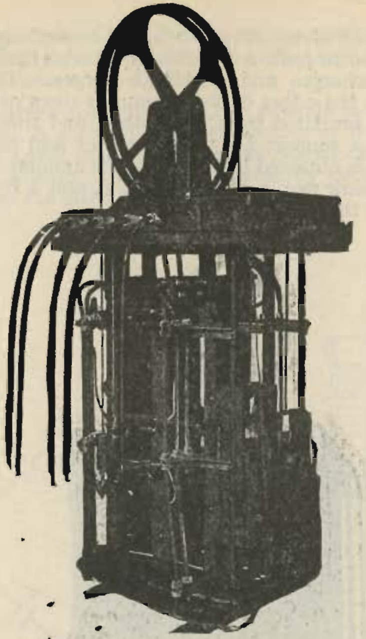


FIG. 2,092.—75 light Westinghouse-Cooper Hewitt mercury vapor rectifier constant current regulating transformer with case removed. The transformer is of the repulsion coil type, oil cooled and oil insulated. It is so arranged as to give a constant secondary current and to insulate the arc lines from the primary circuit. The regulating transformer contains two stationary secondary coils and two moving primary coils balanced against each other. Each secondary coil of the 75 light regulator is wound in two parts, owing to the use of two rectifier bulbs in series in outfits of this capacity. The repulsion between the primary and secondary coils changes the distance between them according to the variation of load, and the induced current in the secondary is thus kept constant. An increase in current causes the primary and secondary coils to separate, and a decrease in current permits them to approach each other, until the normal balance is restored. The moving coils are hung from sheave wheels having roller bearings and are balanced so that they are sensitive to the slightest impulse tending to separate them or draw them closer together. (See figs. 1,981-2, and 2,111.) The windings are insulated for a voltage considerably in excess of that existing in normal service. Several taps are provided to take care of different voltages and wave forms. A combination of taps will be found which will be suitable for any wave form coming within the American Institute of Electrical Engineer's limits for a sine wave. The secondary coils are also provided with taps for 85 per cent. of normal load, so that less than normal load can be taken care of at a good power factor. Any part of the full load can be carried temporarily with the full load connections of the transformer, but at permanent light loads the power factor and efficiency will be improved by using the 85 per cent. connections. Standard regulating transformers are wound for 6.6 and 4 amperes, and for primary circuits of 220, 440, 1,100 2,200, 6,600 and 13,200 volts. Regulators can be specially wound for 5.5 amperes. For three phase circuits three regulators can be used, one on each phase, or they can be furnished in pairs with an auxiliary auto-transformer to give a balanced load. The regulators can be connected, in cases where the unbalancing is not objectionable. to separate phases.

Mercury Vapor Rectifiers.—The Cooper Hewitt mercury vapor rectifier, as shown in fig. 2,093 consists essentially of a *hermetically sealed glass bulb filled with mercury vapor and provided with four electrodes.* The two upper electrodes are of solid material and the two lower of mercury.

The solid electrodes are the positive electrodes; the mercury electrodes are the negative electrodes.

The mercury pools of the two lower electrodes are not in contact when the bulb is vertical, but the bulb is so mounted that it can be tilted to bring these two pools temporarily in contact for starting.

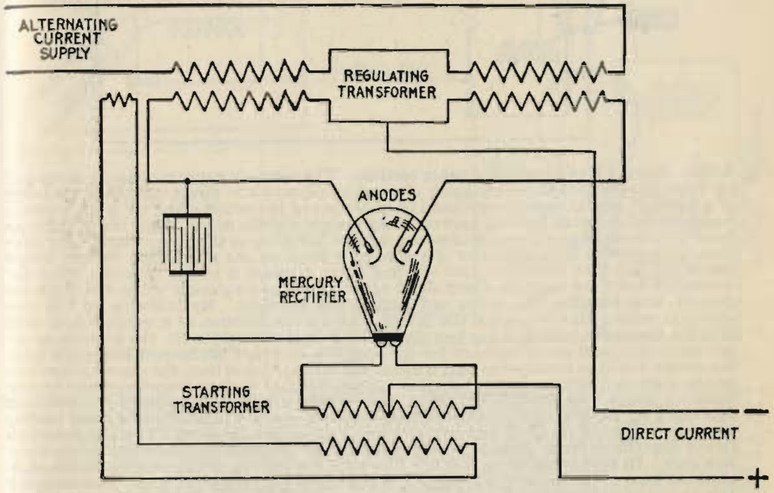


FIG. 2,093.—Diagram of connections of Westinghouse-Cooper Hewitt mercury vapor rectifier arc light circuit.

The bulb contains highly attenuated vapor of mercury, which, like other metal vapors, is an electrical conductor under some conditions. The positve electrodes are surrounded by this